In any event, few jackrabbits sampled in our study area contained elevated levels of lead in tissue and those that did, contained low concentrations (Craig and Craig 1995). Research by Hoffman et al. (1981) on bald eagles suggests that the lead levels in jackrabbit tissues sampled in our study area are not high enough to elevate eagle blood lead levels above the detection limit. This supports the contention that biologically incorporated lead in prey is not the likely avenue of lead contamination to the eagles wintering in our study area. These data also support our finding of no difference in lead levels among the valleys, in spite of the history of lead mining in the Lemhi and Birch Creek Valleys.

The source of lead contamination in raptors is usually thought to be from imbedded lead shot or bullets ingested with the tissues of crippled or dead animals (Hoffman et al. 1981, Pattee et al. 1990, Redig 1980, Eisler 1988). Researchers have found significant differences in mean lead values by month for golden eagles, with the highest values occurring during the winter months and the lowest during the summer (Kramer and Redig 1997, Pattee et al. 1990). Kramer and Redig (1997) also reported that the highest incidences of lead poisoning were during the months of November and December. Similarly, the National Wildlife Health Research Center reported that 88% of the bald eagles diagnosed as having died of lead poisoning were collected from November through March (Anonymous 1992). Although there are few direct data to support the assumption, elevated lead levels in golden and bald eagles during the winter months are often attributed to lead projectiles in the carcasses of hunter-killed or crippled animals (Platt 1976, Pattee and Hennes 1983, Nelson et al. 1989, Pattee et al. 1990).

The eagles in our study area congregate in places where black-tailed jackrabbits are found in the winter. Hunting these hares is a popular winter pastime for people. Eagles often feed on jackrabbits shot and left by hunters (pers. observ.). We have also observed bald and golden eagles feeding on big game animals during the winter, some of which probably died after having been wounded by hunters earlier in the fall. Published accounts of big game deaths due to loss of wounded animals range from 6, 9 and 10% in Montana (Pac et al. 1995) to 27% in northern Idaho (Unsworth et al. 1993). Big game hunting seasons occur during the winter in our study area and golden eagles have been observed to congregate in the areas of these hunts (M. Scott, IDF&G, pers. comm.). We assume that these eagles were feeding on carrion associated with big game hunts and that this is a possible source of lead contamination to eagles within our study area during the winter. Lead projectiles are nearly always used in big game and black-tailed jackrabbit hunting in east central Idaho (pers. observ.). Kramer and Redig (1997) report that lead contamination has persisted in eagles even after the 1991 ban of lead shot in waterfowl hunting. They suggest that lead contamination might be related to the year-round hunting of small mammals and birds and/or offal containing lead fragments that remain in the field during big game hunting seasons.

It is known that free-ranging eagles die from Pb poisoning (Pattee et al. 1981, Redig 1993 Reichel et al. 1984, Craig et al. 1990, Weimeyer et al. 1989, Anonymous 1992, Franson et al. 1995) and that high blood lead levels are indicative of acute exposure to lead (Hoffman et al. 1981, Pattee et al. 1981). However, blood lead levels of most of the golden eagles we have sampled, as well as, those reported by other researchers (Kramer and Redig 1997, Pattee et al. 1990), are in the lowest category of exposure (0.20-0.60 ppm). These lead levels are not likely to be a direct cause of death. However, the effects of this long-term, low-level exposure to Pb on free-ranging eagles is unknown.

Predicting the effects of lead exposure on free-ranging animals is complicated because survival and successful reproduction are influenced by many variables. For example, high absorption rates for calcium (as might occur during egg laying) may increase the absorption of lead. In addition, there is considerable variation in the responses of different avian species to lead exposure (Beyer et al. 1988). However, research on Rock doves (*Columba livia*) showed that chronic exposure to lead interfered with learning behavior (Dietz et al. 1979). If lead exposure affects learning in golden eagles, long-term contamination could adversely affect their survival rates. Similarly, exposure to other contaminants, susceptibility to disease, cold-stress, accidental injury and starvation can all contribute to the death or reproductive failure of an individual already weakened by lead exposure (Kramer and Redig 1997, Kendall 1982, Pattee et al. 1981, Task Group on Metal Accumulation 1973).

We are unaware of controlled laboratory studies on the effects of lead ingestion on golden eagles. However, there have been laboratory studies on the effects of Pb on bald eagles (Pattee et al. 1981, Hoffman et al. 1981). Pattee et al. (1981) found that the individual responses of five bald eagles experimentally dosed with #4 lead shot were quite variable. For example, four of the eagles died from 10 to 125 days after the experiment began. The fifth experimental eagle did not die from lead poisoning although it was fed 80 #4 lead shot pellets during the course of the experiment. Eventually, this bird became blind and was finally sacrificed after 135 days. A subsequent necropsy revealed that 129.0 mg of the lead had been eroded by digestion during the study. Nonetheless, lead levels in liver and kidney were low; 3.2 ppm and 3.4 ppm, respectively. Pattee et al. (1981) concluded that sublethal exposure to lead also can be harmful to bald eagles and can indirectly contribute to their death.

Reports on the effects of Pb on reproduction in raptors have been conflicting. Henny et al. (1994) found reduced reproductive rates in American kestrels (*Falco sparverius*) that nested in a study area contaminated with lead. However, the population-wide productivity of the birds was not significantly different than in a control area. In the same study area, Henny et al. (1991) reported no decrease in overall productivity in an osprey population, although some of the individual birds had elevated lead levels. However, Henny et al. (1991) did not report on the productivity of individual osprey with elevated lead levels. It is interesting to note that the golden eagle with the highest blood lead levels (0.71 ppm) in our study did not nest successfully in 1996.

Elevated blood lead levels have been reported in 30% to 50% of the golden eagles in sampled populations in the western U.S. (this study, Pattee et al. 1990, Harmata and Restani 1995). If sublethal levels of lead have a negative impact on the productivity or survival of golden eagles, then there is the potential for population-wide impacts on golden eagles through time. This may be increasingly significant when considered with the long-term downward trends in golden eagle numbers in the western United States reported by Hoffman et al. (1996).

MERCURY IN GOLDEN EAGLES

The importance of elevated Hg levels in tissues of eagles is not fully understood. Mercury accumulation in the environment is generally related to aquatic systems (Eisler 1987) and the source of Hg to raptors is generally aquatic prey. Although golden eagles in the West have been reported to prey upon fish (Brown 1992), their prey are generally mammalian and avian species in upland habitats (pers. observ., Eakle and Grubb 1986). Thus, they are less likely to be exposed to mercury contamination. The golden eagles in our study did not contain elevated mercury levels, and in most samples, mercury blood lead levels were below the detection limit. Consequently, we discontinued mercury analysis of blood samples from golden eagles after winter 1994-1995.

LEAD IN BALD EAGLES

The sample population of bald eagles wintering in our study area had higher mean lead levels in blood (both arithmetic and geometric means) than the wintering golden eagles sampled. In addition, more wintering bald eagles sampled had elevated blood lead levels than did wintering golden eagles sampled. A spring study of migrating eagles in Montana, (Harmata and Restani 1995) also reported higher blood lead levels in bald than in golden eagles (x = 0.32 ppm wet weight and x = 0.18 ppm wet weight, respectively; geometric means not given). Mean blood lead level of bald eagles in our study area was slightly higher than reported in the Montana study (comparison based on arithmetic means).

The difference in lead levels in bald and golden eagles may result from differences in the food or feeding habits of the two species. Bald eagles are more likely to feed on prey associated with aquatic ecosystems (Terres 1980) and thus be exposed to lead contamination (Reichel et al. 1984, Feierabend and Myers 1984).

MERCURY IN BALD EAGLES

Mercury levels in the blood of bald eagles wintering in our study area were much higher than mercury levels in golden eagles. Wiemeyer et al. (1989) has noted that bald eagles routinely have higher mercury concentrations in their blood than other species of birds. Again, this difference is probably related to dissimilarities in prey between the two species of eagles. Harmata and Restani (1995) also found that mercury levels were higher in vernal migrant bald than in golden eagles in Montana. However, mean blood mercury concentrations in the bald eagles in our study were higher than reported for bald eagles in the Montana study (arithmetic mean: 0.54 ppm; Harmata and Restani 1995). Conversely, the values from our study area were less than those reported for 15 bald eagles from Oregon, northern California and Montana (> 3 ppm mercury in blood; Wiemeyer 1989). Little is known about the relationship of mercury concentrations in blood and exposure rates and their subsequent health consequences (Wiemeyer 1989).

SECTION II. SATELLITE TRACKING OF GOLDEN EAGLES WITH ELEVATED LEAD LEVELS

METHODS

CAPTURE AND SELECTION OF EAGLES

During winter 1995-1996 three male and three female golden eagles with elevated lead levels were captured and fitted with Platform Transmitter Terminals (PTTs) from Microwave Telemetry Inc. (Columbia, MD). The PTTs were attached with teflon ribbon in a backpack configuration (similar to Snyder et al. 1989). Each apparatus weighed 95 gm. (< 3% of the body weight of the eagles). Golden eagles were captured with padded leg-hold traps (after Bloom 1987). All of the golden eagles fitted with telemetry equipment were trapped in the upper Lemhi River Valley. The transmitter numbers were used to identify individual eagles throughout the rest of this paper.

Once captured, the eagles were banded, measured (footpad, wing chord, tarsus and cranium) and photographed. The birds were banded with USF&WS bands on one leg and an alpha-numeric colored band (orange or green) on the other. The 5 cc blood samples were collected by brachial vein puncture and then were placed in heparinized glass tubes and frozen at the end of each day.

All blood samples were analyzed by Lockheed Martin, a Lockheed Idaho Technologies Company in Idaho Falls, Idaho. They determined lead levels with a VG Elemental PlasmaQuad through inductively coupled plasma-mass spectroscopy (ICP-MS). A wavelength of 207.97 nm was used for lead, and an internal standard of indium was used at a wavelength of 114.9 nm. The lower limit of reportable residues was 0.01 ppm (wet weight) for lead in all samples.

TELEMETRY VIA SATELLITE, DATA INTERPRETATION

In order to maximize battery life of the PTT, transmissions were calibrated for 4 programmed "seasons" and transmission cycles:

30 December 1995 - March 31 1996	8 hrs. on 1 day out of 3
1 April - 30 April 1996	8 hrs. on 3 days out of 7
1 May - 30 September 1996	8 hrs. on 1 day out of 7
1 October - end of transmissions	8 hrs. on 3 days out of 7

All transmission receptions were processed by Service Argos, Inc. (Landover, MD). Argos categorizes estimates of the PTT positions in location classes (LC) according to their estimated accuracy (Table 1). Accuracy is dependent upon such variables as the number of messages utilized to calculate PTT position and frequency. Each transmitter contains sensors that monitor temperature, battery voltage, and the activity of the transmitter. This information aids in the interpretation of locations of classes, including 0, A, B, C, or Z. Isolated occurrences of LC's A or lower were not considered reliable data points and so we used them only if they occurred repeatedly in the same area. Our maps of locations of individual birds show LC 3-0 as solid points and all other location classes as open points. Small, round, solid dots on the maps indicate the locations of towns and cities.

Table 1. Description of classification and reliability of satellite location data (Service Argos, Inc., Landover, MD).

LOCATION CLASS	RESOLUTION	# OF SATELLITES
3	68% of all points within 150 meters	4
2	68% of all points within 350 meters	4
1	68% of all points within 1 km	4
0	1000 m+	2 with no auxiliary location processing
A	—	3 + auxiliary location processing
B	—	2 + auxiliary location processing
C	—	2 + auxiliary location processing
Z	—	not enough

Maps and interpretation of data obtained via the satellite system were produced using Ranges V (Kenward and Hodder 1995) and Arcview software (ESRI). Year round range areas were analyzed using convex polygons with number of Incremental Cluster Polygons (groups of locations that separate outliers) identified within the range outline (Hodder et al. 1998).

Seasonal data reported on maps were as follows (based on unpublished migration data from the Snake River Birds of Prey Area, L. Schueck, pers. comm. and Brodeur et al. 1996):

winter – December 1 through March 15;
spring migratory period - March 16 through April 15;
breeding season - April 16 through September 15 and
fall migratory period - September 16 through November 30

We examined the duty cycles from each eagle to determine if movements among individual eagles could be compared. The location estimates from the system were in very similar patterns for the same periods (Appendix A). Therefore, we are confident that similar types of data were collected for each bird and that it is valid to make comparisons among them.

RESULTS

Two PPTs failed within four months after being placed on the eagles. Tracking of one other eagle continued through the spring and fall migration periods of 1996 and on the three remaining eagles through the following winter. Less than 25% of the location estimates were categorized as LCs 3-1 (range: 8.8% -24.5%; Figure 1) for the eagles monitored.

All the eagles we tracked via satellite had elevated lead levels in their blood (Table 2). Five of these birds were in the lowest category of *exposure* to lead (0.20 – 0.60 ppm) and 5727, an adult male, was in the next higher category (0.61 – 1.20 ppm), or *clinically affected* (Kramer and Redig 1997).

Eagle number 5709 was the only adult female golden eagle tracked during the study. Her winter range was 150 km wide and included both the Lemhi and Pahsimeroi Valleys and adjacent areas to the south and east (Figure 2). However, 5709 did not use the area uniformly, but concentrated her activity in much smaller areas within the winter range.

On 31 March 1996, 5709 began moving northward along the western edge of the Continental Divide. She continued north through the panhandle of Idaho to an area just south of Prince George, British Columbia (Figure 3) where she remained for three days. By April 7th, after migrating over 1700 km in 7 days, the PTT stopped